APPENDICES

Appendix A. Table provided to USFWS by T. Reid, Jan. 11, 1999. Summary of habitat acres in various habitat categories for the PALCO SYP/HCP and Headwaters acquisition.

7. A	Summary of Old Growth Redwood and HCP Status – With Final December MMCA Extension												
	Area in acres												
			Othe	OG Dou Fir	REDOG	REDOG	REDOG	All Uncut OGR	REDRS 2	REDRS	All Residual	All OG	Total Area
PL Land													
	Avail for Harvest		175,970	8,304	148	217	81	460	222	7,784	8,225	8,452	192,725
	Buffer Zones		1,963	0	0	0	0	0	0	295	295	295	2,258
	MCA Options												
		Grizzley	410		73	44		117	48	482	530	647	1,057
		Owl Crk	350	19	240	77		317	10	230	239	556	925
	MCA reserve Subtotal		2,849	197	902	98	86	1,087	242	2,155	2,397	3,483	6,529
	Extension												
		Augment Grizzley	120		13			13	42	177	219	232	352
		Augment Owl	136		42			42		97	97	138	274
		Subtotal	255	0	55	0	0	55	42	274	316	371	626
	HCP Reserve Options												
		Preserve Grizzley	3,259	197	976	142	86	1,204	290	2,636	2,927	4,131	7,586
		Preserve Owl	3,199	216	1,142	175	86	1,404	252	2,384	2,636	4,040	7,454
		Preserve Both	3,609	216	1,215	220	86	1,521	300	2,866	3,166	4,687	8,511
	Total Reserve with Extension		3,864	216	1,270	220	86	1,576	342	3,140	3,482	5,058	9,137
	Headwaters		1,927		2,288	584	245	3,117	0	664	665	3,782	5,709
	PL TOTAL		183,724	8,519	3,706	1,021	413	5,139	565	11,882	12,447	17,586	209,830
ERTC Lands													
	Avail for Harvest		7,674					0			0	0	7,674
	Buffer Zones		26					0			0	0	26
	Headwaters		1,769					0			0	0	1,769
	ERTC TOTAL		9,469					0			0	0	9,469
	HCP Study Area TOTAL		193,193	8,519	3,706	1,021	413	5,139	565	11,882	12,447	17,586	219,299
ALL HCP and Purchase Conservation													
		Preserve Grizzley	6,955	197	3,264	726	332	4,321	291	3,301	3,591	7,913	15,064
		Preserve Owl	6,895	216	3,430	759	332	4,521	252	3,049	3,301	7,822	14,932
		Preserve Both	7,305	216	3,503	803	332	4,638	301	3,530	3,831	8,469	15,989
		Reserve with Ext	7,560	216	3,558	803	332	4,693	343	3,804	4,147	8,840	16,616
		Reserve as % of	3.9%	2.5%	96.0%	78.7%	80.3%	91.3%	60.7%	32.0%	33.3%	50.3%	7.6%
ALL Available for Harvest													
		Option Cut Grizzle	186,299	8,304	276	262	81	619	312	8,834	9,146	9,765	204,367
		Option Cut Owl	186,238	8,323	442	295	81	818	274	8,582	8,855	9,674	204,235
		Cut Neither	185,889	8,304	203	217	81	501	264	8,352	8,616	9,117	203,310
		Available with Ex	185,633	8,304	148	217	81	446	222	8,078	8,300	8,746	202,684
		Available as % of	96.1%	97.5%	4.0%	21.3%	19.7%	8.7%	39.3%	68.0%	66.7%	49.7%	92.4%

Appendix B (version1). Height growth in second-growth coastal redwood and Douglas-fir: timing and emergence of habitat features associated with the marbled murrelet (J. Peters, USDI Fish and Wildlife Service, February 1999). **Editor's note**: Due to short deadline, App. B (vers. 1) tables and figures may appear to be out of order in document, but text references are to appropriate table and figure numbers.

Background

(1) The final rule (U.S. Fish & Wildlife Service, 1996) designating critical habitat for the marbled murrelet (*Brachyramphus marmoratus*) discusses the importance of emergent second-growth forests within one-half mile of potential nest sites. Stands with a canopy height of at least one-half the site-potential tree height are considered to reduce the differences in microclimates between forested and unforested sites, to reduce the potential for windthrow during storms, and to provide a landscape that a higher probability of occupancy by marbled murrelets. Forested stands, within one-half mile of potential nest sites, that attain one-half site-potential tree height, based on species-specific site index tables, are designated as critical habitat under the final rule (U.S. Fish & Wildlife Service, 1996).

(2) Even-aged, second-growth stands and even-aged, second-growth cohorts within mixed-age stands immediately adjacent existing and potential nest trees in the Marbled Murrelet Conservation Areas (MMCA's) may make a substantial contribution to habitat quality. Hamer and Nelson (1995) evaluated habitat attributes on and around marbled murrelet nest trees and found that mean nest height in the California sample (n = 10) was 47 meters (154 feet) with a standard deviation of 11 meters (36 feet). Adjacent second-growth approaching a height of 118 feet (the mean value minus one standard deviation) have attained enough size to conceal some nests. Nelson and Hamer (1995a) note that the avoidance of predation is an important adaptive trait in marbled murrelets and outline fifteen predator avoidance strategies observed in that species, including nest concealment. Nelson and Hamer (1995b) review their own data for marbled murrelet nest sites, compare it to the results of several studies of other avian species, and conclude that nest concealment is probably an important factor in limiting murrelet nest predation and in maintaining reproductive efficiency. The marbled murrelet habitat association model by Grenier and Nelson (1995) includes several attributes correlated with occupancy that can be construed as providing nest concealment.

Questions Addressed

(1) What portion of the second-growth landbase within one-half mile of potential marbled murrelet nest sites will attain an average height of one-half site potential tree height (SPTH) within the 50-year life of the proposed Habitat Conservation Plan submitted by the Pacific Lumber Company? The immediate task, addressed here, is to identify database search parameters to enable a solution to the landbase question.

(2) Over the next 50 years, what portion of the second-growth cohorts, in mixed-age, mosaic-pattern stands in the Marbled Murrelet Conservation Areas (MMCA's), will attain an average

height of 120 feet, thereby providing nest concealment and improving the reproductive potential of breeding adults? Again, the immediate task is to identify database search parameters to enable a quantitative solution.

Summary and Explanation of the Attached Tables and Figures

Figure 1

The figure (from Oliver and Larson, 1990) illustrates stratification in a forest canopy. The consensus view within the FWS is that the height of the upper continuous canopy should be the standard for determining if a stand has attained a reference height (such as one-half SPTH). In the figure, this canopy level is termed the "B-stratum." Other descriptors are coined and used for this level of the canopy and are reasonably interchangeable (main canopy, codominant canopy); provided there is a clear understanding that the stratum of interest is the tallest, continuous canopy level that does not include dominants or emergents ("A-stratum").

Figure 1

Canopy Stratification
(The "B-Stratum" is Treated as the General Canopy Height)

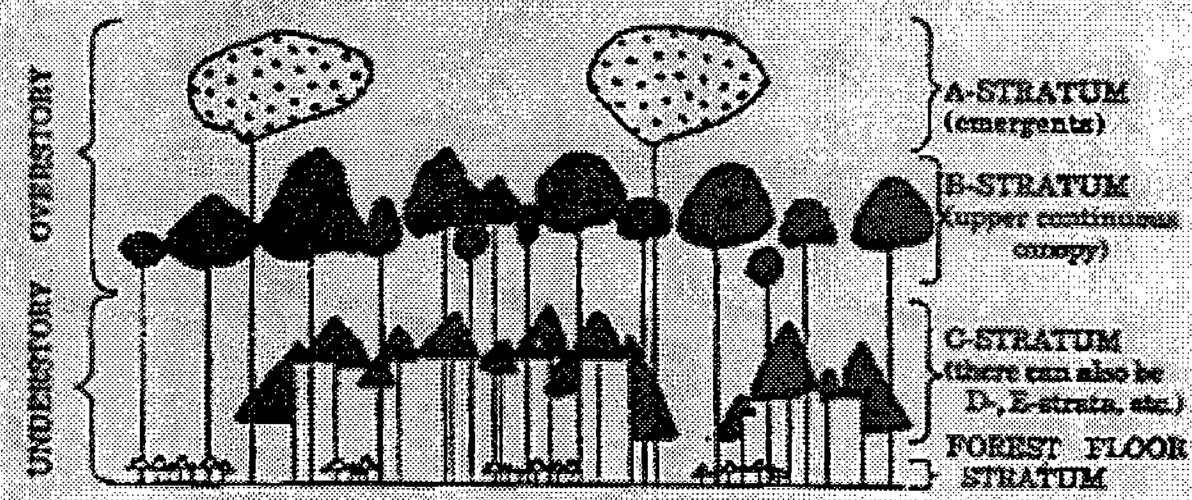


Table 1

A summary of the descriptive attributes of the successional (or seral) stages used in the Pacific Lumber Co. Draft HCP (1998). The stages are based on the ones used in the California wildlife habitat relations system (Mayer and Laudenslayer, 1988). Note that tree diameter is the defining attribute. Other attributes are for descriptive purposes only. The Service added right-hand column (stratification stage) for additional descriptive power.

Table 1. Successional (seral) stage descriptions used in the PALCO Draft HCP (1998).

Seral stage[1]	Age range (years)[2]	Dbh range (inches)[3]	WHR Equivalent[4]	Stratification stage[5]
Opening	0 to 10	0 to 1.0	seedling[1]	stand initiation
Young	10 to 20	1.1 to 6.0 6.1 to 11.0	sapling[2] pole[3]	stem exclusion
Mid-seral	20 to 50	11.1 to 24.0	small tree[4]	stem exclusion
Late-seral	>55 (± 5)	>24.0	medium to large tree[5]	possible understory reinitiation
Old-growth	none given	>30.0	multi-layered tree[6]	well developed strata

[1]– PALCO Draft HCP (1998), Volume I, page 17.
[2]– Age ranges are for descriptive purposes only. They do not define the seral stage in the Draft HCP, nor in the underlying State of California Wildlife Habitat Relations system (Mayer and Laudenslayer 1988).
[3]– Dbh ranges define the seral stages in the Draft HCP and in Mayer and Laudenslayer (1988).
[4]– Equivalent terminology (with code numbers in parentheses) from Mayer, K. E. and W. F. Laudenslayer. 1988. A guide to the wildlife habitats of California. The Resources Agency, Sacramento CA.
[5]– Equivalent stand development descriptors used in: Oliver, C. D. and B. C. Larson. 1990. Forest stand dynamics. McGraw-Hill, Inc., New York.

Figure 2 and Table 4

Illustrates mean height and mean diameter (breast height, or DBH) ranges for the seral stages used in the Pacific Lumber Co. Draft HCP (1998). Transition diameters for the seral stages come from the Pacific Lumber Co. Draft HCP (1998), as derived from Mayer and Laudenslayer (1988). The mean height curve and height intercepts were generated from a mean height-DBH equation provided by Vestra Resources, Inc. (1998). The equation, below, is based on Pacific Lumber Co. timber inventory data.

$$\text{Mean Height} = (5.552468 * \text{DBH}) - (0.0438 * \text{DBH}^2) \quad [\text{correlation coefficient} = 0.753]$$

Table 4 shows a sample of mean heights for DBH's ranging from 20.0 inches to 40.6 inches.

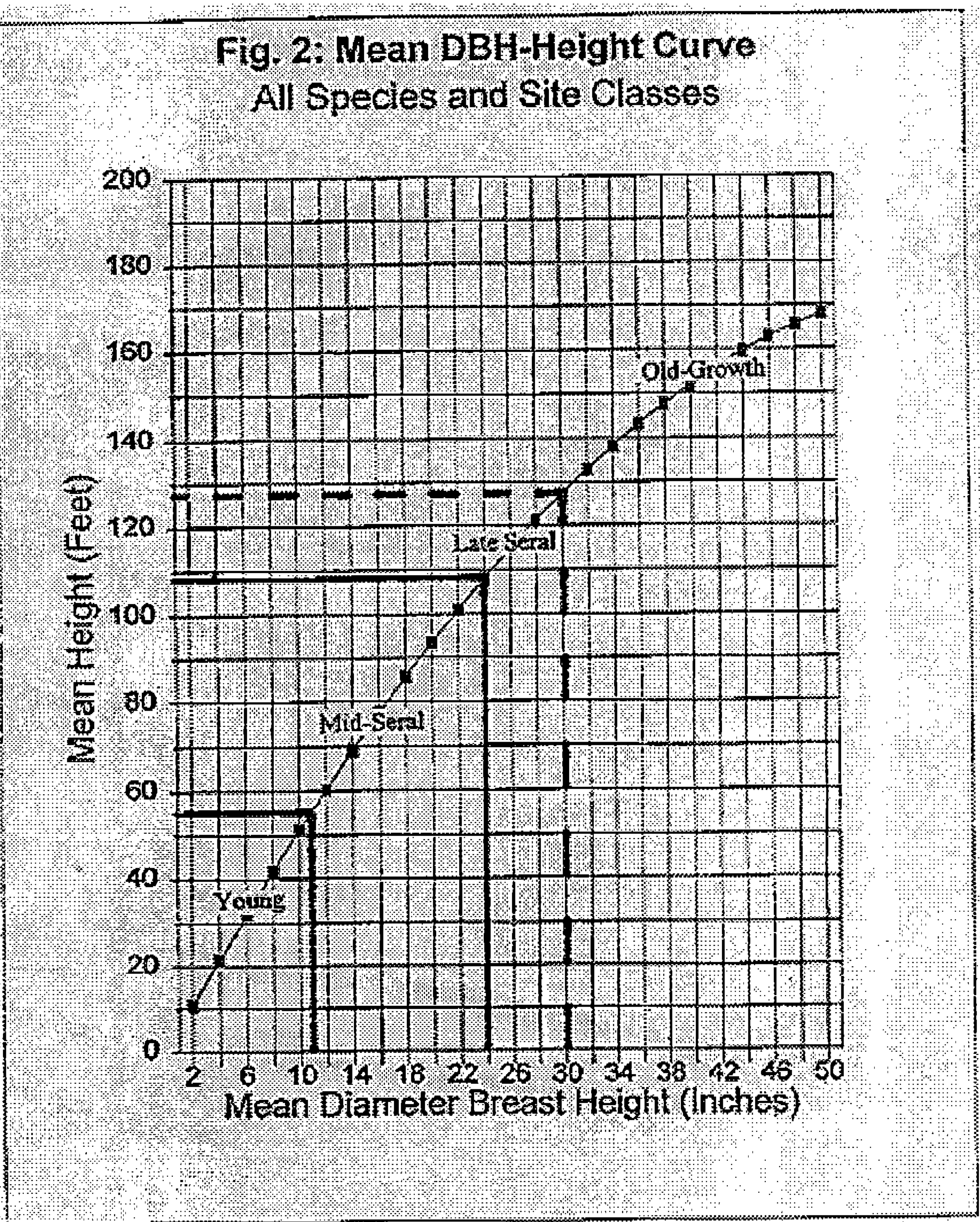


Fig. 2: Mean DBH-Height Curve
All Species and Site Classes
Mean Height (Feet)
200
180
160
140
120
100
80
60
40
20
0
Young
Mid-Seral
Late Seral
Old-Growth
2
6
10
14
18
22
26
30
34
38
42
46
50
Mean Diameter Breast Height (Inches)

Table 4. Relationship of average height to average diameter breast height (dbh)							
Avg dbh (inches)	**Avg height (feet)**	**Avg dbh (inches)**	**Avg height (feet)**	**Avg dbh (inches)**	**Avg height (feet)**	**Avg dbh (inches)**	**Avg height (feet)**
20.0	93.5	25.2	112.1	30.4	128.3	35.6	142.2
20.2	94.3	25.4	112.8	30.6	128.9	35.8	142.6
20.4	95.0	25.6	113.4	30.8	129.5	36.0	143.1
20.6	95.8	25.8	114.1	31.0	130.0	36.2	143.6
20.8	96.5	26.0	114.8	31.2	130.6	36.4	144.1
21.0	97.3	26.2	115.4	31.4	131.2	36.6	144.5
21.2	98.0	26.4	116.1	31.6	131.7	36.8	145.0
21.4	98.8	26.6	116.7	31.8	132.3	37.0	145.5
21.6	99.5	26.8	117.3	32.0	132.8	37.2	145.9
21.8	100.2	27.0	118.0	32.2	133.4	37.4	146.4
22.0	101.0	27.2	118.6	32.4	133.9	37.6	146.9
22.2	101.7	27.4	119.3	32.6	134.5	37.8	147.3
22.4	102.4	27.6	119.9	32.8	135.0	38.0	147.8
22.6	103.1	27.8	120.5	33.0	135.5	38.2	148.2
22.8	103.8	28.0	121.1	33.2	136.1	38.4	148.6
23.0	104.5	28.2	121.7	33.4	136.6	38.6	149.1
23.2	105.2	28.4	122.4	33.6	137.1	38.8	149.5
23.4	105.9	28.6	123.0	33.8	137.6	39.0	149.9
23.6	106.6	28.8	123.6	34.0	138.2	39.2	150.4
23.8	107.3	29.0	124.2	34.2	138.5	39.4	150.8
24.0	108.0	29.2	124.8	34.4	139.2	39.6	151.2
24.2	108.7	29.4	125.4	34.6	139.7	39.8	151.6
24.4	109.4	29.6	126.0	34.8	140.2	40.0	152.0
24.6	110.1	29.8	126.6	35.0	140.7	40.2	152.4
24.8	110.8	30.0	127.2	35.2	141.2	40.4	152.8
25.0	111.4	30.2	127.7	35.4	141.7	40.6	153.2

The height equation, based on Pacific Lumber Co. inventory data, was provided by Vestra Resources, Inc., Redding CA (1998). The equation is: Avg height = (5.52468 * Avg dbh) + (- 0.04358 * (avg dbh^2) [r-square = 0.753].

Table 2, Figures 4, 5, 6 and 7

The top half of Table 2, along with Figures 4 and 6, show the relationship of dominant height to age (breast height) for redwood and Douglas-fir. Height-age tables and curves were computed for each species for site classes 1, 2 and 3. The mean site index (height at the reference age of 50-years) for each site class is shown in Table 3, based on information in the Pacific Lumber Co. draft HCP (1998), Volume III, Part B, page 7. Height solutions are based on dominant height equations by Wensel and Krumland (1986) for redwood and by King (1966) for Douglas-fir.

The bottom half of Table 2, along with Figures 5 and 7, show the relationship of mean (or average) height to age (breast height) for redwood and Douglas-fir. Mean-height-age tables and curves were computed for site classes 1, 2 and 3, in the same format as dominant height. Mean-height solutions for Douglas-fir and redwood are based on a ratio of mean height to dominant height (m/d) such that, for a given stand age and site index,

$$\text{Mean Height} = \text{Dominant Height} * (m/d)$$

The ratio of mean to dominant height for both species resulted from a review of modeling results for Douglas-fir (Curtis, et al., 1982). The DFSIM Douglas-fir stand simulator (Curtis, et al., 1981) yields two stand height outputs in each simulation cycle; the "Ht40" (defined as the mean height of the tallest forty trees per acre, equivalent to dominant height), and the "Lorey Height" (defined as the height of the tree of mean cubic foot volume, the closest equivalent we could find to the height of the "B-stratum" or codominant layer). We selected these as surrogates for dominant and mean height, respectively. Lacking the means to compute mean tree volumes, we then searched for a more direct relationship between "Lorey height" and "Ht40" in the simulation output tables (Curtis, et al., 1982). The search revealed that m/d ratios clustered around 0.78 at age 20, and 0.89 at age 100, and that the trend in ratios appeared to be independent of site index and prior thinning history. The increasing trend in ratios with increasing age indicates that mean and dominant heights would converge at around age 200. We then drew a small number of data points from the simulation tables in Curtis, et al. (1982) and constructed a simple linear regression solving the m/d ratio as a function of stand age. The resulting equation is,

$$m/d \text{ Ratio} = 0.7555 + (0.001222 * \text{Age}),$$

and the final mean height equation becomes,

$$\text{Mean Height} = \text{Dominant Height} * (0.7555 + (0.001222 * \text{Age})).$$

Table 2. Age-height relationship for coastal redwood and Douglas-fir.						
Part 1– Dominant height table						
Species and site class	**Redwood**			**Douglas-fir**		
	Site 1	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Breast-height age	**(dominant height in feet)**					
0	0	0	0	0	0	0
20	60	52	43	69	59	49
40	101	86	71	121	103	85
60	131	112	93	158	134	110
80	154	132	111	184	156	128
100	172	149	125	204	172	141
120	186	161	136	220	185	151
140	197	172	146	233	195	159
160	206	180	154	243	204	165
180	213	187	160	252	211	170
200	219	193	166	260	216	175
Part 2– Mean, or average, height table						
Species and site class	**Redwood**			**Douglas-fir**		
	Site 1	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Breast-height age	**(mean height in feet)**					
0	0	0	0	0	0	0
20	47	40	34	54	46	38
40	81	69	57	97	83	69
60	108	93	77	131	111	91
80	131	113	94	157	133	109
100	151	130	110	179	151	123
120	168	146	123	199	167	136
140	183	159	135	216	181	147
160	196	172	146	232	194	157
180	208	183	156	246	205	166
200	219	193	166	260	216	175

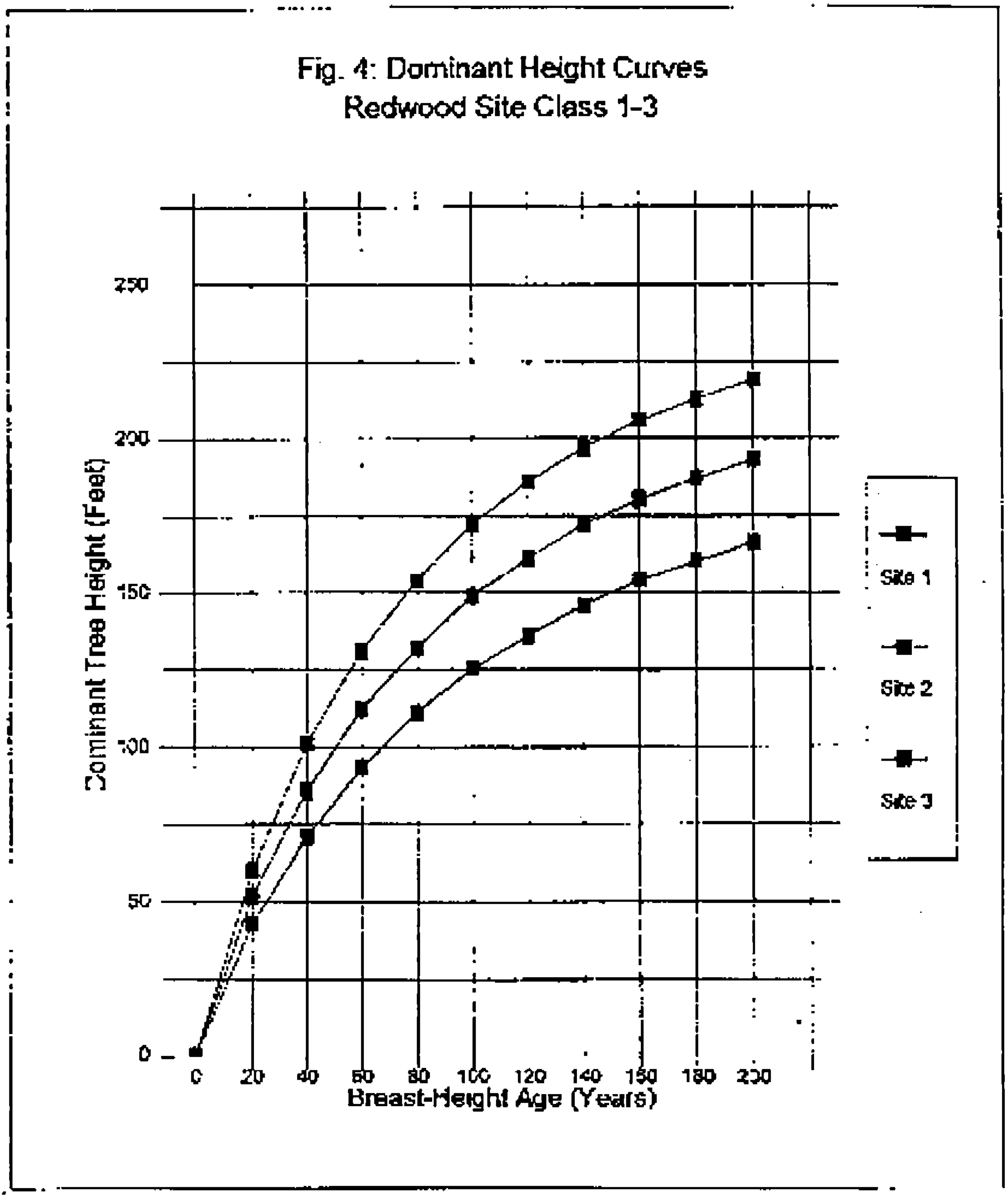


Fig. 4: Dominant Height Curves
Redwood Site Class 1-3
Dominant Tree Height (Feet)
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
200
Breast-Height Age (Years)
Site 1
Site 2
Site 3

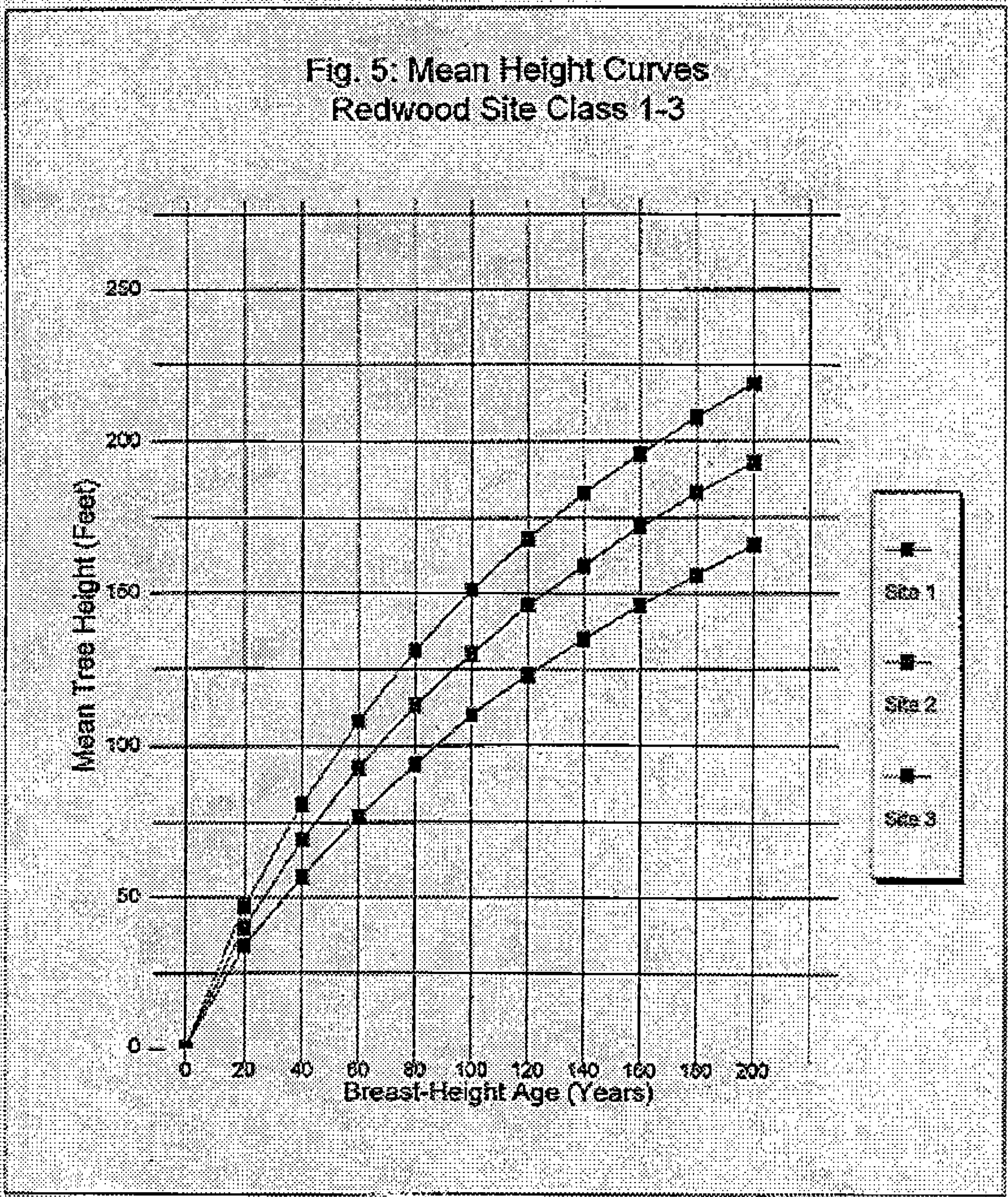


Fig. 5: Mean Height Curves
Redwood Site Class 1-3
Mean Tree Height (Feet)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180
200
Breast-Height Age (Years)
Site 1
Site 2
Site 3

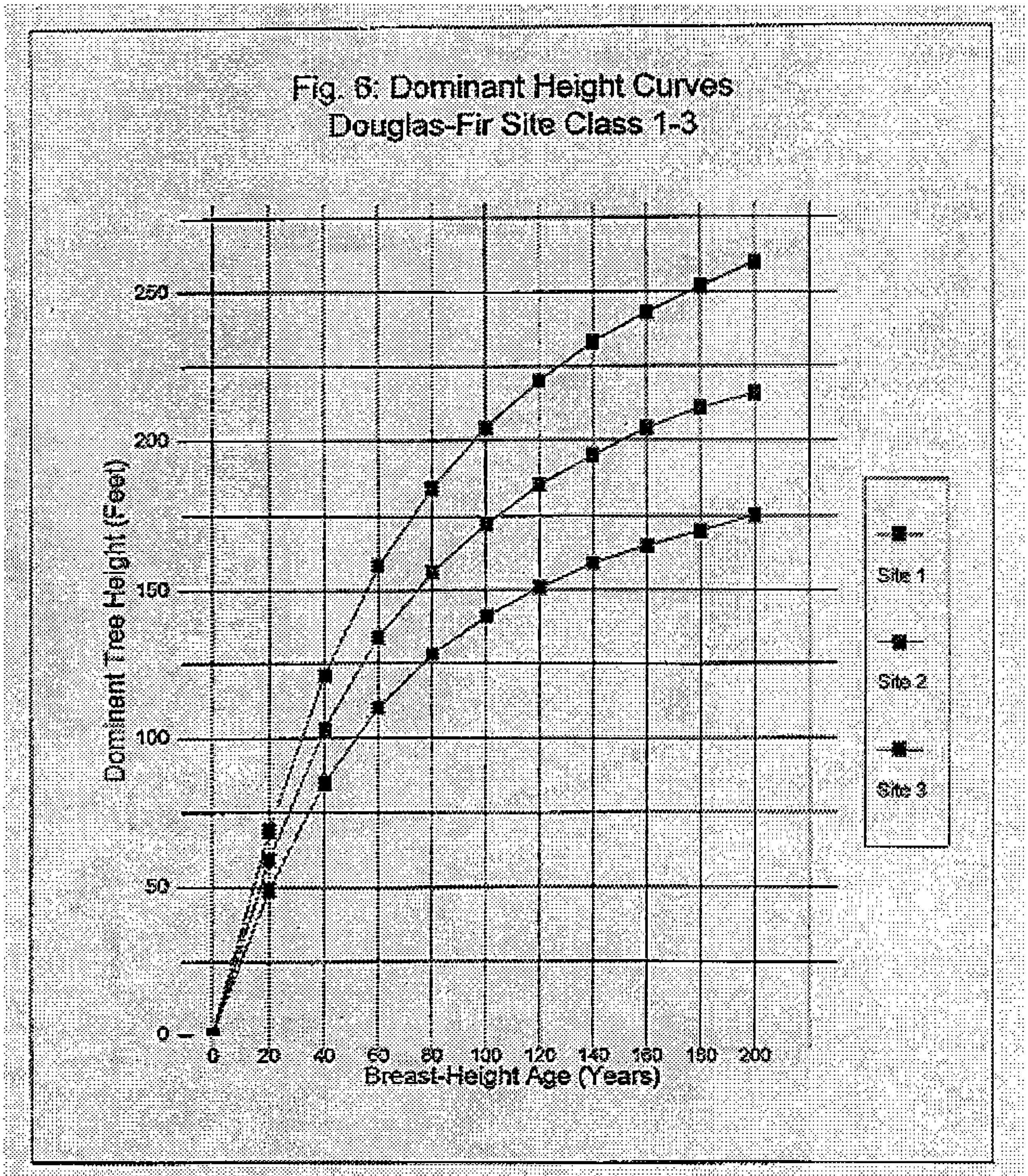


Fig. 6: Dominant Height Curves
Douglas-Fir Site Class 1-3
Dominant Tree Height (Feet)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180
200
Breast-Height Age (Years)
Site 1
Site 2
Site 3

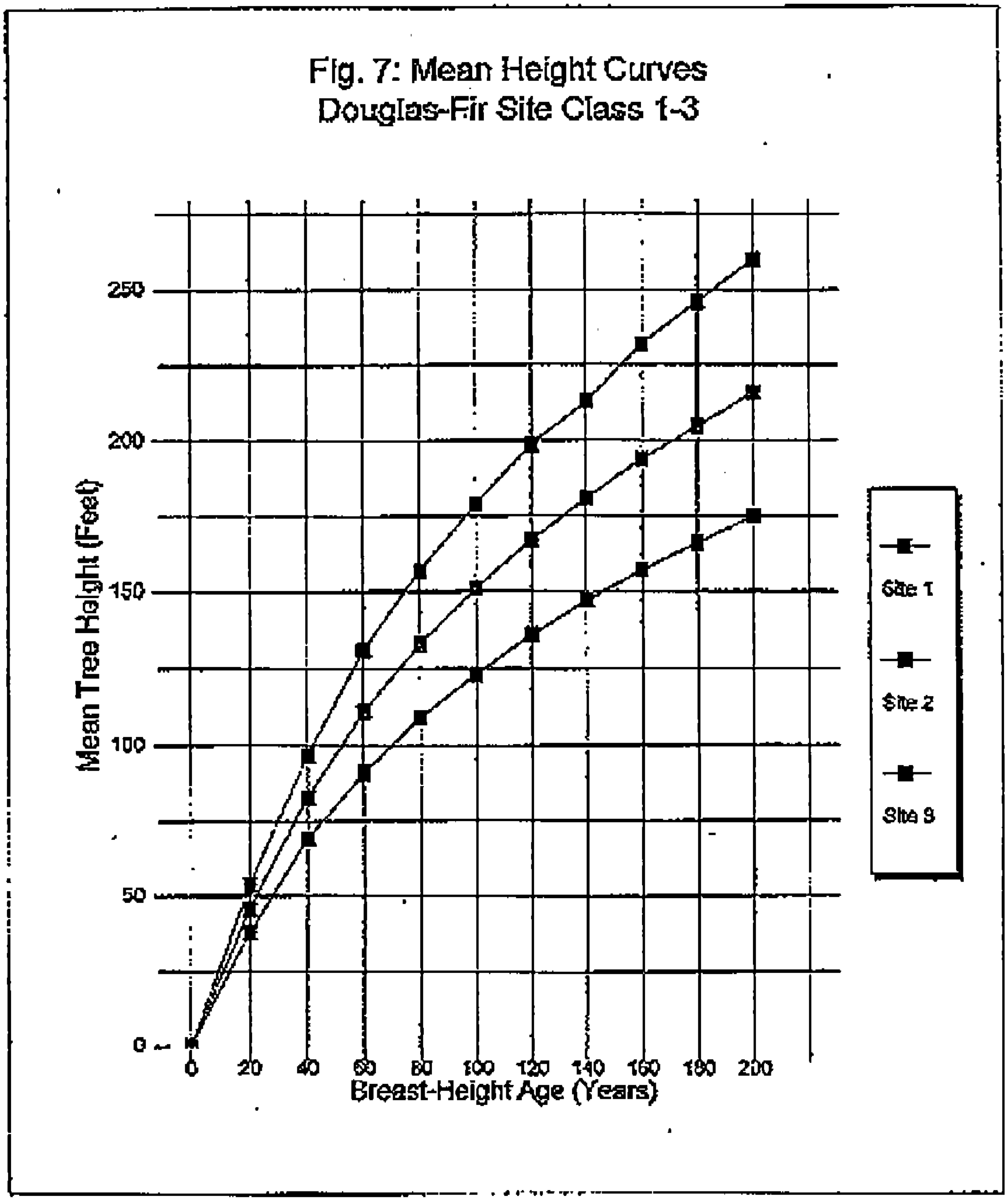


Fig. 7: Mean Height Curves
Douglas-Fir Site Class 1-3
Mean Tree Height (Feet)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180
200
Breast-Height Age (Years)
Site 1
Site 2
Site 3

Figure 3 and Table 3

Site-potential tree heights were estimated for site classes 1, 2 and 3 using dominant height growth equations for redwood (Wensel and Krumland, 1986) and Douglas-fir (King, 1966). Each species and site class was projected 600 years or more until annual height growth approached zero, or a very low number. Figure 3 is a sample 600-year projection for redwood, site class 2 (notice in Table 3 that SPTH for redwood site class 2 was attained at 625 years. Figure 3 was one of several iterations used to establish that SPTH and corresponding age). Redwood dominant-height projections arrived at zero height growth at ages of 500, 625 and 675 years for sites classes 1, 2 and 3, respectively. Douglas-fir height projections did not attain zero height growth at any age (the longest projection was 1,500 years), but did closely approach zero. It is not known whether this reflected biological reality or if it was an artifact of the equations, which were not designed to simulate growth in older age classes. In order to set a definitive height and age for Douglas-fir, I set an arbitrary standard that SPTH was attained when annual height growth diminished to 0.2 feet per year. This occurred at 450, 400 and 350 years for site classes 1, 2 and 3, respectively. Site potential tree heights, age at SPTH, age at one-half SPTH and the breast-height age corresponding to a mean tree height of 120 feet (along with other parameters) are summarized for redwood and Douglas-fir (all site classes) in Table 3.

One significant issue with this method (for determining SPTH) is the use of contemporary (polymorphic) height growth equations (e.g., Wensel and Krumland, 1986; King, 1966) to estimate future heights at ages of 350 years, and beyond, while the source publications indicate the equations were derived from much younger sample trees (e.g., 10-80 years for Wensel and Krumland, 1986). While this approach is an unavoidable compromise, there is also evidence that the compromise is justified. Following are the three major points in that line of reasoning.

(a) The use of polymorphic height growth equations, based on younger sample trees, is becoming unavoidable. Because of their computational flexibility, polymorphic height equations are a critical subroutine in stand growth models. For example, the Wensel and Krumland (1986) height equations are embedded in the CRYPTOS and CRYPT2 models (Krumland and Wensel, 1982) for the redwood region, and the King (1966) equations are mimicked in the DFSIM model (Curtis, et al., 1981) for Pacific northwest Douglas-fir. As a consequence of these technological linkages, public and private forestland managers are increasingly collecting and reporting their site index information to conform with the most current site index and height growth models applicable to their landholding.

(b) In contrast, the earlier site index and height growth models (e.g., Dunning, 1942; McArdle, et al., 1949; Lindquist and Palley, 1963) used a mechanical plotting technique, called the guide curve method, that yielded graphical outputs, but no least-squares solutions and no equations. Some of the older guide curve-based graphs are instructive because they plot height and age out to 250 years and beyond (e.g., Dunning, 1942; McArdle, et al., 1949), and clearly show the older regions of the curves where annual height growth levels-off. This enables the user to graphically visualize the meaning of site potential tree height as defined in FEMAT (1993). However, others (e.g., Lindquist and Palley, 1963) only plot height growth to 100 years, an age-region where growth is still fairly rapid, leaving the user with no ready means to project the curves to the age of maximum of maximum height.

(3)Even though the polymorphic height equations of Wensel and Krumland (1986) and King (1966) rely on a young tree sample base, they appear to perform reasonably well in long projections of 300 years and more. In their general form, the polymorphic height curves closely resemble the published long-age-span height projections by Dunning (1942) and McArdle, et al. (1949). I made a test projection of 500 years using the highest redwood site index (160 feet at 50 years) in Wensel and Krumland (1986). That projection attained a site potential tree height of 300 feet at 480 years and did not surpass any of the documented "giant" redwoods on alluvial flats in State and National Parks; including the "big tree" in Redwood National Park (386 ft), the Dyersville Giant (372 ft) and the Montgomery Woods "giant" (367 ft). We consider this a credible outcome for two reasons: (a) alluvial flats supporting "giant" trees are exceptional sites, many in public ownership, so we would not expect sites of this quality to be well-represented in Wensel and Krumland's (1986) sample base; and (b) because the coefficients in the height growth equation are a product of sample means. Consequently, the equation solutions should be expected to fall short of the upper limit of tallest trees in a second-growth stand, let alone the tallest trees on record anywhere.

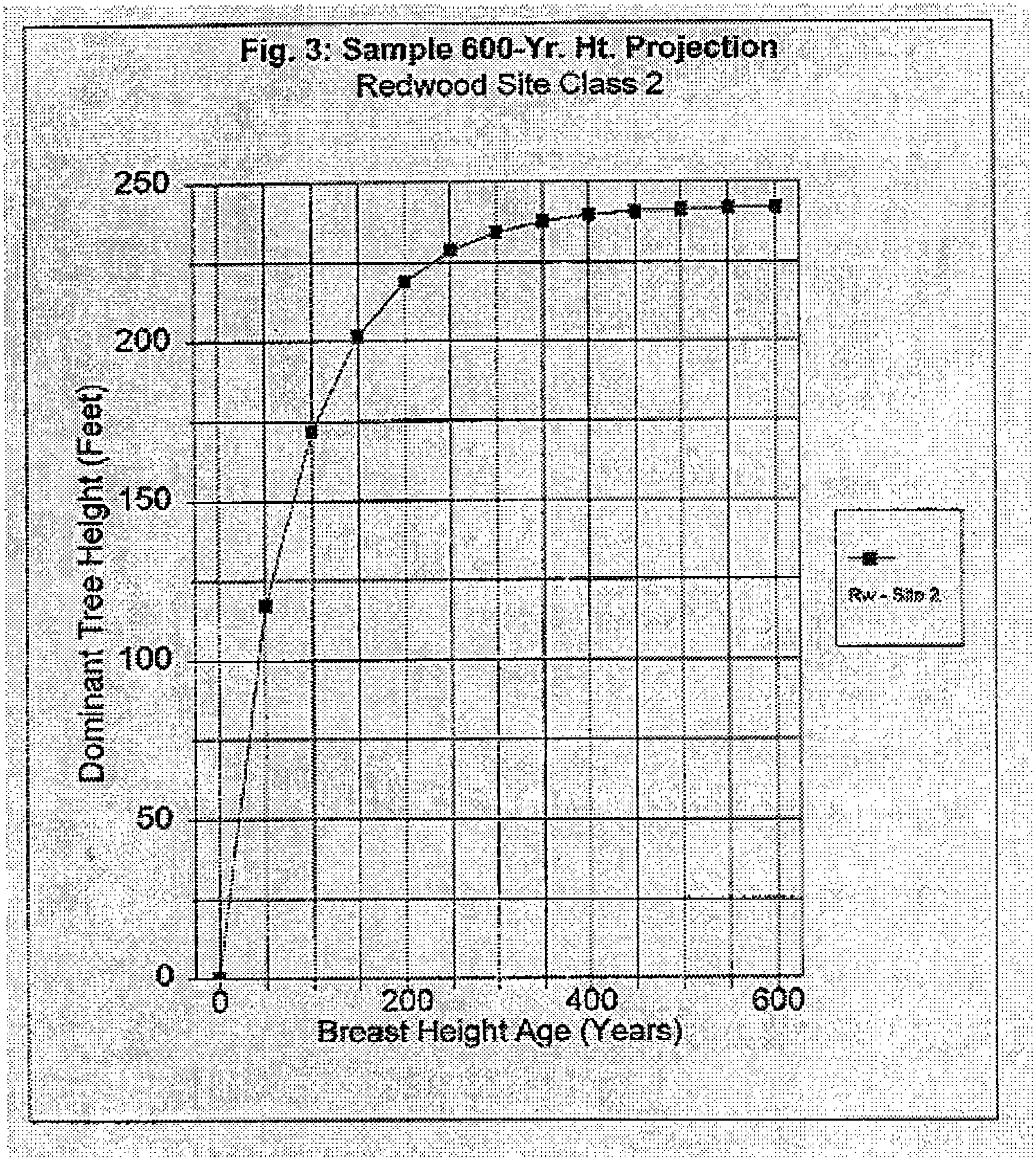


Fig. 3: Sample 600-Yr. Ht. Projection
Redwood Site Class 2
Dominant Tree Height (Feet)
250
200
150
100
50
0
0
200
400
600
Breast Height Age (Years)
Rw - Site 2

Table 3. Height growth and age attributes of coast redwoods and Douglas-fir.						
Site attribute	**Redwood**			**Douglas-fir**		
Site class[1]	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Site index, height at 50 years[1, 2, 3]	117 ft	100 ft	83 ft	141 ft	120 ft	99 ft
Site potential tree height (SPTH)[4, 5]	242 ft	218 ft	192 ft	304 ft	248 ft	194 ft
Estimated age at SPTH [4, 5]	500 yrs	625 yrs	675 yrs	450 yrs	400 yrs	350 yrs
One-half SPTH[6]	121 ft	109 ft	96 ft	152 ft	124 ft	97 ft
Estimated age at one-half SPTH[7]	71 yrs	76 yrs	82 yrs	76 yrs	71 yrs	66 yrs
Mean dbh at one-half SPTH[8]	28.0 in	24.3 in	20.6 in	40.0 in	28.9 in	20.9 in
Estimated age at 120' height[7]	70 yrs	88 yrs	115 yrs	53 yrs	68 yrs	95 yrs
Seral Stage[9]	**Does the seral stage dbh exceed the mean dbh above?**					
Forest opening (0.0 - 1.0" dbh)	no	no	no	no	no	no
Young (1.1 - 11.0" dbh)	no	no	no	no	no	no
Mid-seral (11.1 - 24.0" dbh)	no	no	partly	no	no	partly
Late-seral (>24" dbh)	partly	partly	fully	partly	partly	fully
Old-growth (includes trees>30" dbh)	fully	fully	fully	fully	fully	fully

[1]– Published in the PALCO Draft HCP (1998), Volume III, page 7.
[2]– Redwood site index and height equations from Wensel, L. C. and B. Krumland. 1986. Hilgardia 54(8):1-14.
[3]– Douglas-fir site index and height equations from King, J. E. 1966. Weyerhaeuser Forestry Paper No. 8. Centralia, WA.
[4]– Redwood age and height was projected 600 years using Wensel and Krumland (1986) height growth equations. Site potential tree height, and corresponding age, were set where annual height growth diminished to zero.
[5]– Douglas-fir age and height was projected 600 years using King (1966) height growth equations. Site potential tree height, and corresponding age, were set where annual height growth diminished to 0.2 feet per year.
[6]– Site potential tree height divided by two.
[7]– Minimum age at one-half site potential tree height, and 120 ft. height, was read from the 600-year age-height projections in [4] and [5] above.
[8]– A dbh-height equation, based on PALCO inventory data, was supplied by Vestra Resources Inc., Redding CA (1998). The equation is: Avg ht = (5.52468 * Avg dbh) + (- 0.04358 * (avgdbh^2) [r-square = 0.753].
[9]– Based on Mayer, K. E. and W. F. Laudenslayer. 1988. A guide to wildlife habitats of California. The Resources Agency, Sacramento CA.

Tables 5 and 6, Figures 8, 9, 10 and 11

I next made 150-year projections, in 5-year intervals, for redwood and Douglas-fir (all site classes). At each 5-year interval, the projection displayed breast-height age, dominant height and mean height. In the tables, I used the current mean height of trees (in 10-foot increments) as a starting point to represent the variety of height classes that may be present in the field. Then using the 150-year projections, I calculated, by subtraction, the years that would elapse between the current mean height and the reference mean height; either 120 feet (Table 5, Figures 8 and 9), or one-half SPTH (Table 6, Figures 10 and 11). All mean height and age values falling between the 5-year intervals were corrected to the nearest year and the nearest foot by interpolation. On Figures 8, 9, 10 and 11, a horizontal line is projected at 50-years, representing the 50-year timespan of the proposed HCP. All curve segments that lie below the 50-year line encompass the current mean height classes that will attain reference mean height (120 feet or one-half SPTH) within the life of the proposed HCP.

Table 5. Years to grow from current average height to an average height of 120 feet.

Species and site class	**Rw site 1**	**Rw site 2**	**Rw site 3**	**Df site 1**	**Df site 2**	**Df site 3**
Reference height	120 feet	120 feet	120 feet	120 feet	120 feet	120 feet
Reference age	70	88	115	53	68	95
	Years required to attain an average height of 120 feet					
Average height today (feet)	**Rw site 1**	**Rw site 2**	**Rw site 3**	**Df site 1**	**Df site 2**	**Df site 3**
0	70	88	115	53	68	95
10	66	84	111	51	64	90
20	62	79	105	46	60	85
30	58	74	98	42	56	80
40	53	68	90	38	51	74
50	49	62	82	34	46	68
60	43	55	73	30	41	62
70	38	47	63	26	36	54
80	31	39	52	21	30	46
90	24	31	41	17	23	36
100	17	22	29	12	17	26
110	9	13	15	6	9	14

Table 6. Years to grow from current average height to one-half site potential tree height.						
Species and site class	**Rw site 1**	**Rw site 2**	**Rw site 3**	**Df site 1**	**Df site 2**	**Df site 3**
Reference height	121 feet	109 feet	96 feet	152 feet	124 feet	97 feet
Reference age	71 years	76 years	82 years	76 years	71 years	66 years
	Years required to attain one-half site potential tree height					
Average height today (feet)	**Rw site 1**	**Rw site 2**	**Rw site 3**	**Df site 1**	**Df site 2**	**Df site 3**
0	71	76	82	76	71	66
10	67	72	78	72	67	60
20	63	67	72	69	62	55
30	59	62	65	65	58	50
40	55	56	57	61	54	45
50	49	50	49	57	49	39
60	44	43	40	53	44	33
70	38	35	30	49	39	25
80	30	27	19	45	33	17
90	25	19	8	40	27	7
100	18	9	–	35	20	–
110	10	–	–	29	14	–
120	1	–	–	23	3	–
130	–	–	–	16	–	–
140	–	–	–	9	–	–
150	–	–	–	2	–	–
160	–	–	–	–	–	–

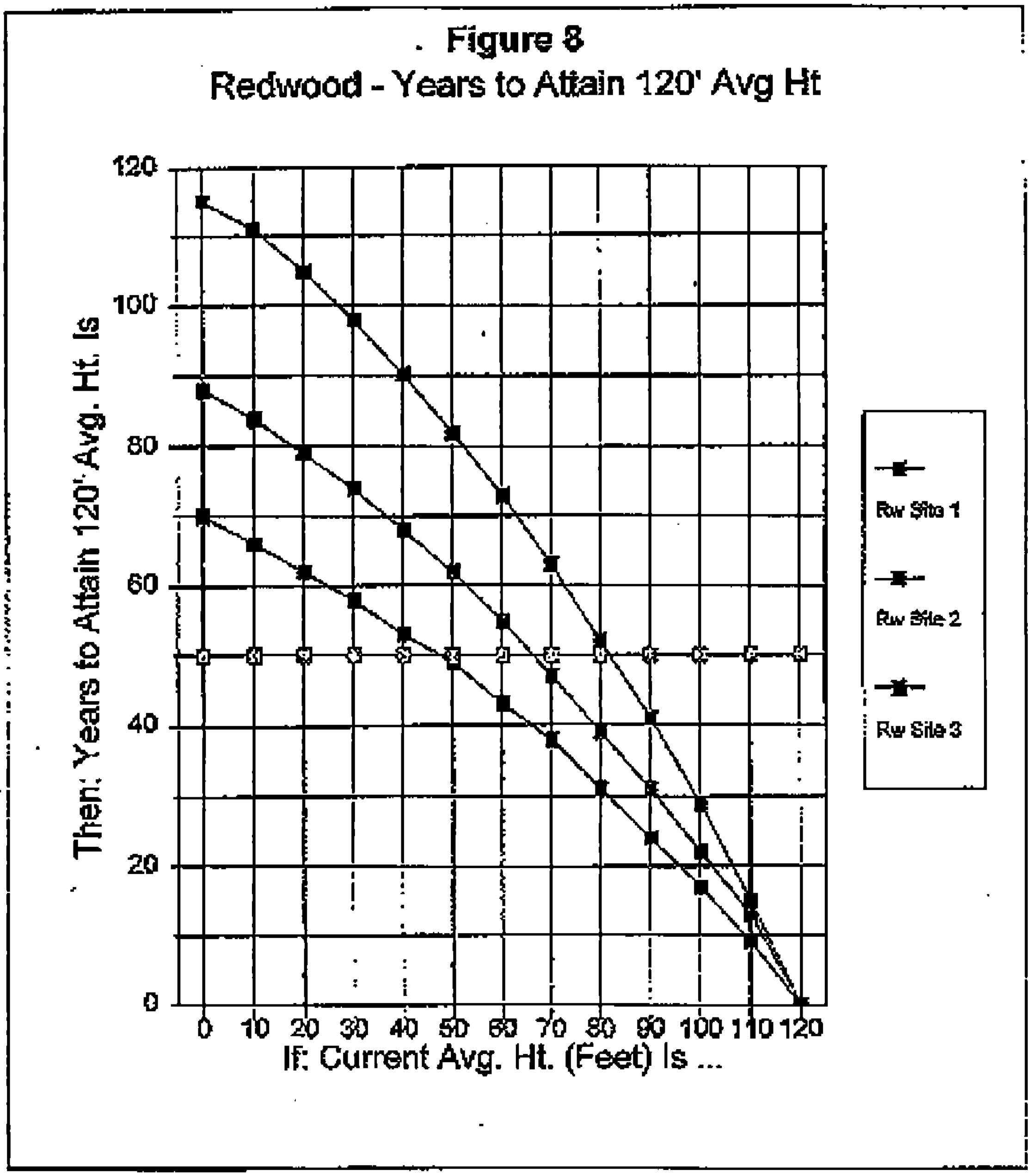
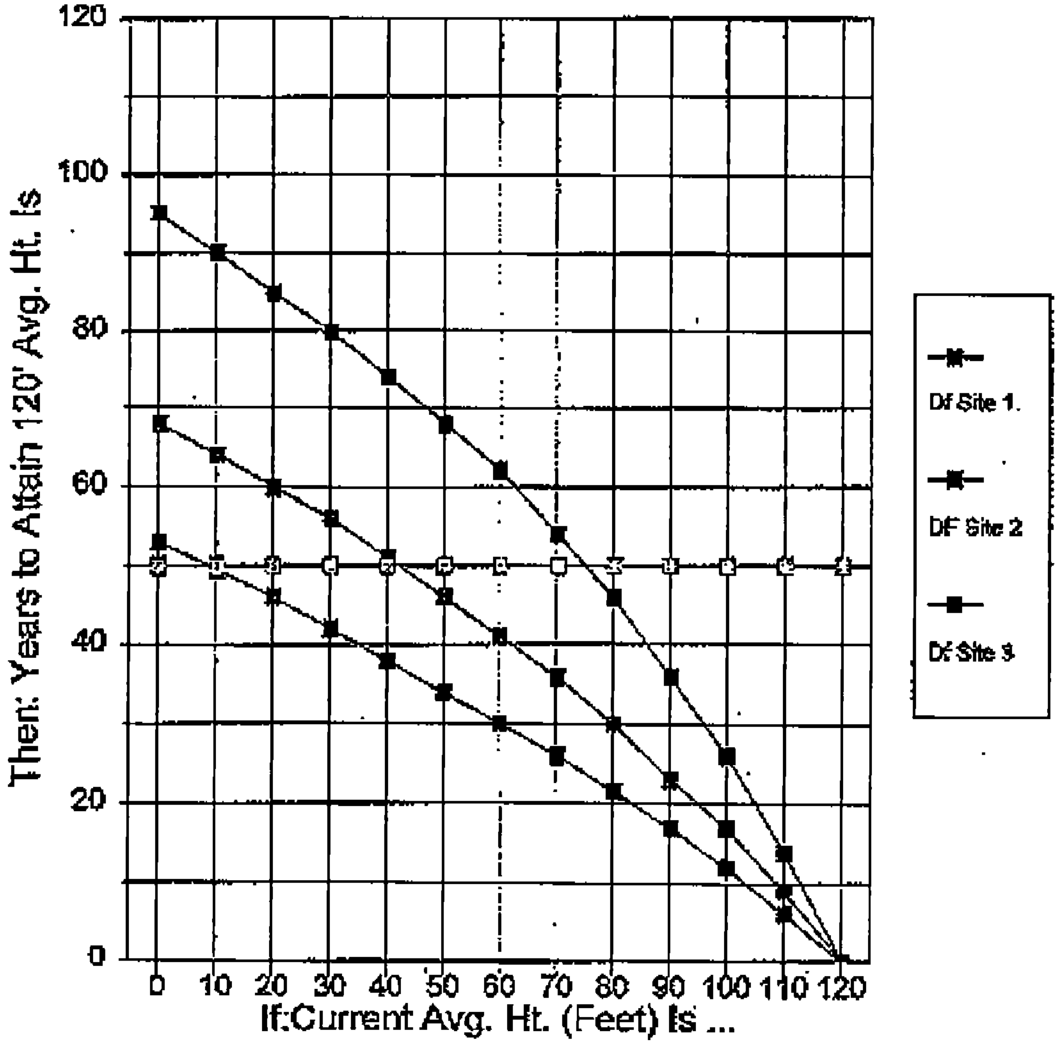

. Figure 8
Redwood - Years to Attain 120' Avg Ht
Then: Years to Attain 120' Avg. Ht. Is
If: Current Avg. Ht. (Feet) Is ...
120
100
80
60
40
20
0
0 10 20 30 40 50 60 70 80 90 100 110 120
Rw Site 1
Rw Site 2
Rw Site 3

Figure 9
Doug-Fir - Years to Attain 120' Avg Ht



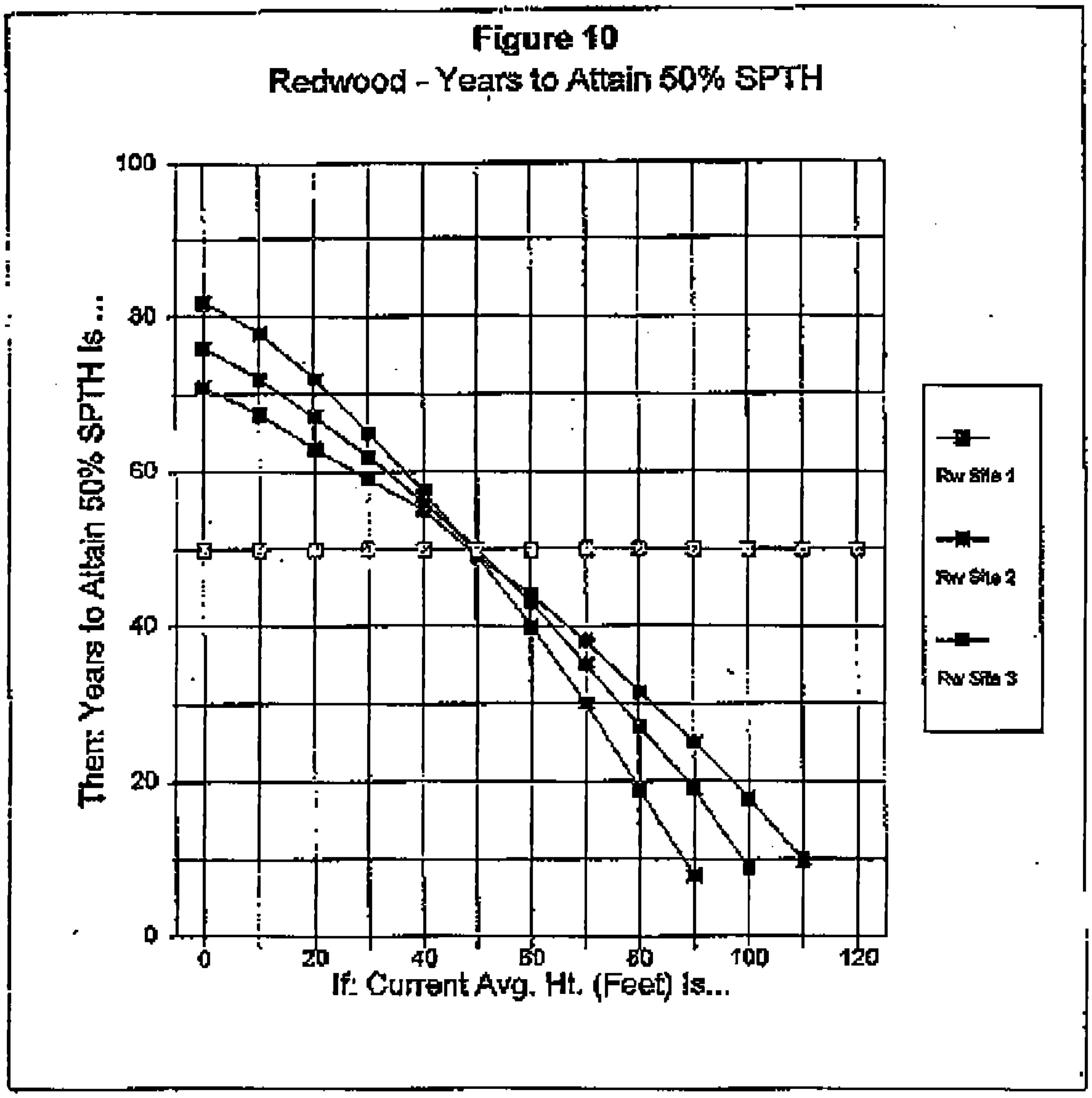


Figure 10
Redwood - Years to Attain 50% SPTH
Then: Years to Attain 50% SPTH Is ...
If: Current Avg. Ht. (Feet) Is...
100
80
60
40
20
0
0
20
40
60
80
100
120
Rw Site 1
Rw Site 2
Rw Site 3

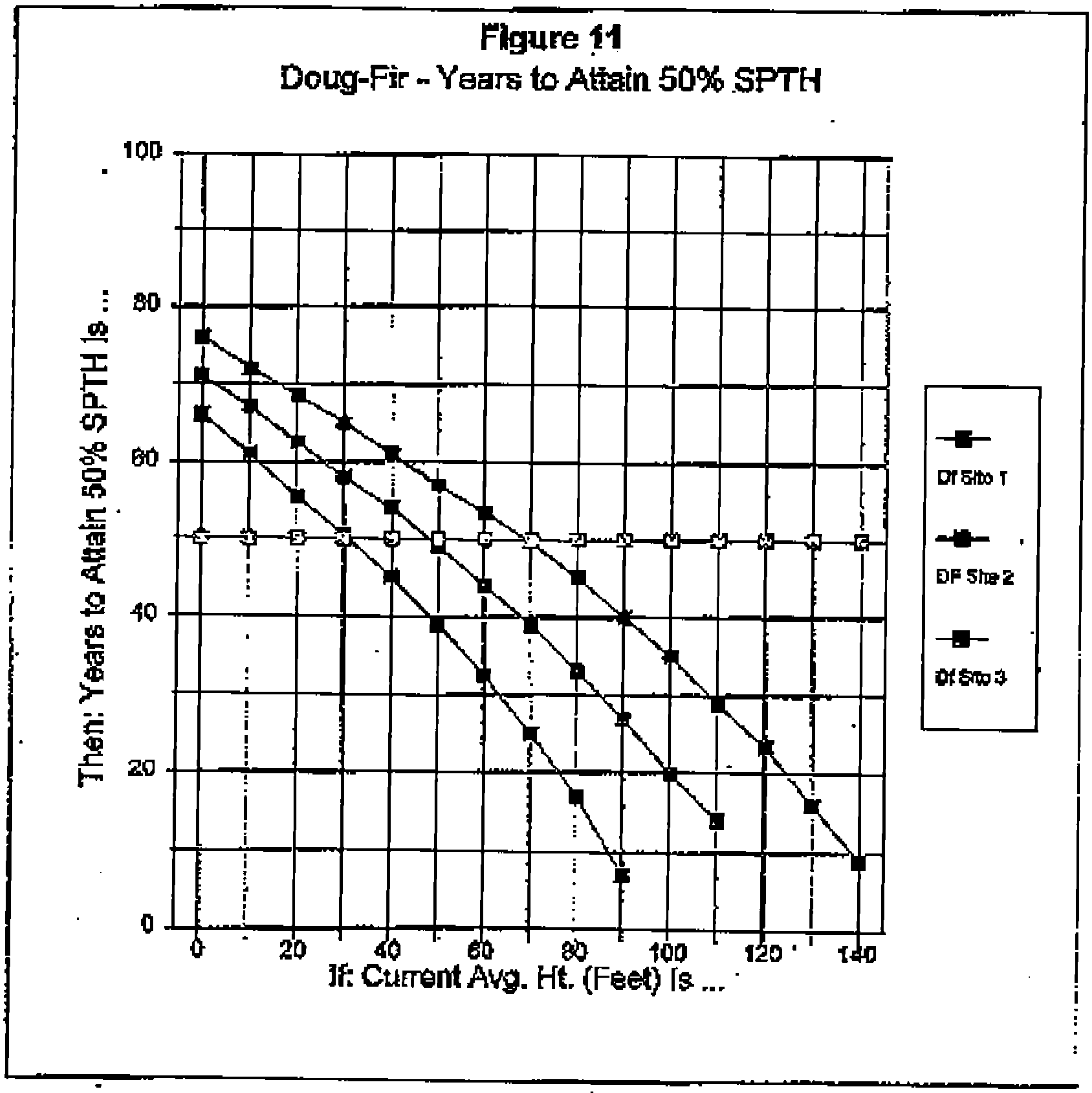


Table 7

This table shows minimum attributes for stands expected to attain references heights (120' or one-half SPTH) within 50 years. Mean stand height, dominant stand height and breast height age were drawn from the 5-year interval projections that were used to build Tables 5 and 6. Total, or groundline, age was calculated from the breast height age using adjustment factors in Wensel and Krumland (1986). Mean diameter (breast height) was reverse-computed from the mean stand height table entry, using the Vestra (1998) equation.

Table 7. Database search attributes for coast redwood and Douglas-fir height attainment.

Part 1– Minimum current attributes for stands expected to attain an average height of 120 feet in the 50-year life of the HCP.

Current stand attributes [1]	Redwood			Douglas-fir		
Site class	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Mean stand height (feet)	47	66	82	8	42	65
Dominant stand height (feet)	60	82	98	11	54	81
Breast height age (years) [2]	27	37	84	4	24	50
Total, or groundline, age (years) [2]	34	45	93	10	31	58
Mean dbh (inches)	9.2	13.3	17.1	1.5	8.1	13.1

Part 2– Minimum current attributes for stands expected to attain one-half site potential tree height in the 50-year life of the HCP.

Current stand attributes [1]	Redwood			Douglas-fir		
Site class	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Mean stand height (feet)	50	50	49	31	48	69
Dominant stand height (feet)	64	63	61	41	62	85
Breast height age (years) [2]	22	26	32	12	21	40
Total, or groundline, age (years) [2]	29	34	41	18	28	48
Mean dbh (inches)	9.8	9.8	9.6	5.9	9.4	14.0

[1]– Use the following guidelines in database search: (a) All attribute values, above, are minima; the database search is for stand or inventory attributes greater than or equal to the minima. (b) Stands retrieved through database search must be well stocked, even-aged, second-growth, or must contain well stocked, even-aged second-growth cohorts in a multi-aged stand. © Dominant height and average height are the most reliable search attributes– use them first. (d) If the database does not contain height information, the next most reliable attributes are breast height and total age. (e) If height or age information is not available, use average diameter breast height. (f) before data retrieval, know how current the inventory data is; young stand growth is quite rapid and the results will be significantly downward-biased if they are based on data more than about 5 years old. This will produce a systematic underestimate of the amount of land expected to attain reference heights in the 50-year life of the HCP.

[2]– Breast height age is the age of the tree at 4.5 feet above the groundline. This is the standard height where increment corings are usually extracted. Total age is the age at groundline. In many second-growth databases, this is usually set at the date when the prior stand was harvested and regenerated. Be certain of which type of age data is in the database. Incorrect assumptions about the age data in the database may result in systematic overestimates or underestimates of the amount of land that will attain reference heights (also see remarks in footnote 1). The height growth equations used in this analysis (King 1966; Wensel and Krumland 1986) are based on breast height age. Total age estimates, above, are based on adjustment factors in Wensel and Krumland (1986).

Table 8

This table shows which current seral stages can be expected to attain reference heights (120 feet or one-half SPTH) within the 50-year life of the proposed HCP. The information is based on data in Table 7 and on the time-series curves in Figures 8, 9, 10 and 11. Table 8 was developed using the following procedure: (a) Transition mean heights were computed for the maximum diameter (breast height) in each seral stage (see Table 1) using the Vestra (1998) equation. The transition heights are 5.5 feet for forest opening, 55.8 feet for young, and 108.0 feet for mid-seral. (b) The transition heights were then projected onto Figures 8 through 11, from the x-axis to the 50-year line. This produced four rectangular polygons between the x-axis and the 50-year line corresponding to the opening, young, mid-seral and late-seral stages. © If the time series curve for a given species and site class fails to intersect a seral stage polygon below the 50-year line, then none of the seral stage landbase will attain reference height within 50 years. (d) If a time-series curve enters a seral stage polygon from the left (through a transition height line), then the entire seral stage landbase will attain the reference height within 50 years. (e) If a time-series curve enters a seral stage polygon through the top line (or 50-year line), then only a portion of the seral stage landbase will attain reference height within 50 years. In that case, the breakpoint diameter from Table 7 is entered in Table 8.

Table 8. Expected seral stage transitions for coast redwood and Douglas-fir height attainment.[1]

Part 1– Portion of the seral stages, below, which will attain an average height of 120 feet in the 50-year life of the HCP.

Forest species	Redwood			Douglas-fir		
Site class	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Forest opening (0.0 - 1.0" dbh)	none	none	none	none	none	none
Young (1 - 11" dbh)	□9.2" dbh	none	none	□1.5" dbh	□8.1" dbh	none
Mid-seral (11 - 24" dbh)	all	□13.3" dbh	□17.1" dbh	all	all	□13.1" dbh
Late-seral (>24" dbh)	all	all	all	all	all	all
Old-growth (includes >30" dbh)	all	all	all	all	all	all

Part 2– Portion of the seral stages, below, which will attain one-half site potential tree height in the 50-year life of the HCP.

Forest species	Redwood			Douglas-fir		
Site class	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Forest opening (0.0 - 1.0" dbh)	none	none	none	none	none	none
Young (1 - 11" dbh)	□9.8" dbh	□9.8" dbh	□9.6" dbh	□5.9" dbh	□9.4" dbh	none
Mid-seral (11 - 24" dbh)	all	all	all	all	all	□14.0" dbh
Late-seral (>24" dbh)	all	all	all	all	all	all
Old-growth (includes >30" dbh)	all	all	all	all	all	all

1– The data table above was made in the following steps:
(a) Transition mean heights were computed from maximum diameter (breast-height) in each seral stage using the Vestra (1988) equation. The transition heights are as follows: Forest opening, 5.5 feet; young, 55.8 feet; mid-seral, 108.0 feet.
(b) The transition heights were projected onto figures 8, 9, 10, and 11, from the x-axis to the 50-year line. This produced four rectangular polygons below the 50-year line corresponding to the opening, young, mid-seral, and late-seral stages.
(c) If the time-series curve for each site class fails to intersect a seral stage polygon below the 50-year line, then none of the seral stage landbase will attain the reference height within the 50-year life of the proposed Habitat Conservation Plan.
(d) If the time-series curve enters a seral stage polygon from the left, then the entire seral stage landbase will attain the reference height within 50 years.
(e) If a time-series curve enters a seral stage polygon from the top, then only a portion of the seral stage landbase will attain reference height within 50 years. In that case, the breakpoint diameter (breast-height) from table 7 is entered.

References

Curtis, R.O., G.W. Clendenen and D.J. DeMars. 1981. **A New Stand Simulator for Coast Douglas-Fir: DFSIM User's Guide**. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. General Technical Report PNW-128. Portland, OR.

Curtis, R.O., G.W. Clendenen, D.L. Reukema and D.J. DeMars. 1982. **Yield Tables for Managed Stands of Coast Douglas-Fir**. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. General Technical Report PNW-135. Portland, OR.

Dunning, D. 1942. **A Site Classification for the Mixed Conifer Selection Forests of the Sierra Nevada**. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. Research Note No. 28. Berkeley, CA.

FEMAT (Forest Ecosystem Management Assessment Team). 1993. **Forest Ecosystem Management: An Ecological, Economic and Social Assessment**. USDA Forest Service; USDI, Bureau of Land Management; USDI Fish and Wildlife Service; USDI, National Park Service; USDoC, National Oceanic and Atmospheric Administration; USDoC, National Marine Fisheries Service; Environmental Protection Agency. Portland, OR.

Grenier, J.J. and S.K. Nelson. 1995. Marbled murrelet habitat associations in Oregon. Chapter 19, *In* C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael and J.F. Piatt (eds.). **Ecology and Conservation of the Marbled Murrelet**. USDA Forest Service, Pacific Southwest Experiment Station. General Technical Report PSW-GTR-152. Albany, CA.

Hamer, T.E. and S.K. Nelson. 1995. Characteristics of marbled murrelet nest trees and nesting stands. Chapter 6, *In* C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael and J.F. Piatt (eds.). **Ecology and Conservation of the Marbled Murrelet**. USDA Forest Service, Pacific Southwest Experiment Station. General Technical Report PSW-GTR-152. Albany, CA.

King, J.E. 1966. **Site Index Curves for Douglas-Fir in the Pacific Northwest**. Weyerhaeuser Forestry Paper No. 8. Weyerhaeuser Forestry Research Center, Centralia, WA.

Krumland, B. and L.C. Wensel. 1982. **CRYPTOS/CRYPT2 Users Guide, Version 4.0**. Redwood Research Note No. 20. Department of Forestry and Resource Management, University of California, Berkeley.

Lindquist, J.L. and M.N. Palley. 1963. **Empirical Yield Tables for Young-Growth Redwood**. California Agricultural Experiment Station, Bulletin No. 796. Berkeley, CA.

McArdle, R.E., W.H. Meyer and D. Bruce. 1949 (Revised 1961). **The Yield of Douglas-Fir in the Pacific Northwest**. U.S. Department of Agriculture, Technical Bulletin 201. Washington, D.C.

Mayer, K.E. and W.F. Laudenslayer. 1988. **A Guide to the Wildlife Habitats of California**. The Resources Agency. Sacramento, CA.

Nelson, S.K. and T.E Hamer. 1995a. Nesting biology and behavior of the marbled murrelet. Chapter 5, *In* C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael and J.F. Piatt (eds.). **Ecology and Conservation of the Marbled Murrelet**. USDA Forest Service, Pacific Southwest Experiment Station. General Technical Report PSW-GTR-152. Albany, CA.

Nelson, S.K. and T.E Hamer. 1995b. Nest success and the effects of predation on marbled murrelets. Chapter 8, *In* C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael and J.F. Piatt (eds.). **Ecology and Conservation of the Marbled Murrelet**. USDA Forest Service, Pacific Southwest Experiment Station. General Technical Report PSW-GTR-152. Albany, CA.

Oliver, C.D. and B.C. Larson. 1990. **Forest Stand Dynamics** (First Edition). McGraw-Hill, New York.

Pacific Lumber Co. 1998. **Draft Sustained Yield Plan and Habitat Conservation Plan, Volume III**. Scotia, CA.

U.S. Fish and Wildlife Service (Dept. of the Interior). 1996. Final designation of critical habitat for the marbled murrelet; final rule. **Federal Register** 61(102): 26256-26320.

Vestra Resources, Inc. 1998. (Unpublished) **Mean DBH-height equation, based on Pacific Lumber Co. inventory data**. Redding, CA.

Wensel, L.C. and B. Krumland. 1986. A site index system for redwood and Douglas-fir in California's north coast. **Hilgardia** (54(8): 1-14.

Appendix C. Habitat Stages for Tree Dominated Habitats in California

Available Habitat Stages for Tree Dominated Habitats

Tree Habitat		Habitat Stage																	
		1	2S	2P	2M	2D	3S	3P	3M	3D	4S	4P	4M	4D	5S	5P	5M	5D	6
SCN	Subalpine Conifer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
RFR	Red Fir	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
LPN	Lodgepole Pine	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
SMC	Sierran Mixed Conifer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
WFR	White Fir	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
KMC	Klamath Mixed Conifer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DFR	Douglas-fir	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
JPN	Jeffrey Pine	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
PPN	Ponderosa Pine	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
EPN	Eastside Pine	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
RDW	Redwood	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PJN	Pinyon-Juniper	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
JUN	Juniper	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
CPC	Closed-Cone Pine-Cypress	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
ASP	Aspen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MHC	Montane Hardwood-Conifer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MHW	Montane Hardwood	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
BOW	Blue Oak Woodland	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
BOP	Blue Oak—Digger Pine	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
VOW	Valley Oak Woodland	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
COW	Coastal Oak Woodland	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
MRI	Montane Riparian	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
VRI	Valley Foothill Riparian	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Standards for tree size

WHR	WHR Size Class	Conifer Crown Diameter	Hardwood Crown Diameter	dbh
1	Seedling tree	n/a	n/a	<1"
2	Sapling tree	n/a	<15'	1"-6"
3	Pole tree	<12'	15'-30'	6"-11"
4	Small tree	12'-24'	30'-45'	11"-24"
5	Medium/large tree	>24'	>45'	>24"
6	Multi-layered tree	Size class 5 trees over a distinct layer of size class 4 or 3 trees, total tree canopy exceeds 60% closure		

Standards for canopy closure

WHR	WHR Closure Class	Ground Cover (Canopy Closure)
S	Sparse cover	10-24%
P	Open cover	25-39%
M	Moderate cover	40-59%
D	Dense cover	60-100%

Source: Mayer, K. E. and W. F. Laudenslayer. 1988. A Guide to Wildlife Habitats of California. California Department of Forestry and Fire Protection, State of California. 166 pp.

Appendix D. Spatial data analysis sources.

The Resources Agency, California Timberland Task Force. 1993. Report of the California Timberland Task Force, 78 pp. This product is classified LandSat imagery, based on a modified WHR classification, with a resolution of 40 acres. A comprehensive accuracy assessment accompanies the product.

Vestra Resources, Inc. Modeling of vegetation for Pacific Lumber Lands. This product contains seral stages, northern spotted owl habitat, WHR types, silvicultural prescriptions, and other labels with future projections by decade, derived from Pacific Lumber Company's timber inventory data.

Pacific Lumber Company. Several GIS coverages used in this analysis were obtained from the Company, including: ownership boundary, streams, roads, watershed analysis areas, slope classifications, marbled murrelet survey results, marbled murrelet conservation areas, rock pit locations,

Humboldt State University. The 1:100,000 scale stream data assembled by Humboldt State University as part of the Klamath Basin Ecosystem Restoration Office contract for GIS data development was used to analyze the action area outside of Pacific Lumber Company ownership. This data was used as a surrogate for the Class1/Class2 stream data available for Pacific Lumber Company ownership, for the purposes of quantifying habitat for riparian associated species.

North Coast Geographic Information Cooperative. Additional data sets, obtained from various sources, and maintained by the NCGIC were used in analyzing the action area, the bioregion, marbled murrelet conservation zone 4, and the regional area. These coverages included: 1:100,000 scale ownership boundaries, Calwater watershed boundaries, and the marbled murrelet conservation zone boundary.

U.S. Fish and Wildlife Service. Several GIS coverages developed by the U.S. Fish and Wildlife Service were used in analyzing the action area, the bioregion, the marbled murrelet conservation zone 4, and the regional area. These include; marbled murrelet zones, marbled murrelet critical habitat, northern spotted owl critical habitat.

Oregon State northern spotted owl and bald eagle point location data. These points were obtained from the U.S. Fish and Wildlife Service Office of Technical Support, Portland, OR.

California Department of Fish and Game, Wildlife Management Division. Statewide GIS data coverages depicting northern spotted owl and bald eagle point locations were obtained, and used in the analysis on Pacific Lumber Company ownership, the action area, and the regional area.